

Attorney Docket No. 00037/LH

**IN THE UNITED STATES PATENT  
AND TRADEMARK OFFICE**



CERTIFICATE OF MAILING

Applicant(s): Y. USAMI, ET AL

Serial No. : 09/490,631

Filed : January 24, 2000

For : ELECTRIC NETWORK  
SIMULATING METHOD,...

Art Unit :

Examiner :

hereby certify this correspondence is being deposited with the United States Postal Service as First Class mail in an envelope addressed to: Commissioner of Patents and Trademarks, Washington, D.C. 20231 on the date noted below.

Attorney: Leonard Hertz

Dated: April 13, 2000

In the event that this Paper is late filed, and the necessary petition for extension of time is not filed concurrently herewith, please consider this as a Petition for the requisite extension of time, and to the extent not tendered by check attached hereto, authorization to charge the extension fee, or any other fee required in connection with this Paper, to Account No. 06-1378.

**SUBMISSION OF ACCURATE ENGLISH TRANSLATION**

Assistant Commissioner for Patents  
Washington, D.C. 20231

Att: Application Branch

S I R :

Responsive to the Patent Office Notice mailed March 30, 2000 the term for response to which expires on May 30, 2000, submitted herewith are the following:

1. Accurate English Translation of the above-identified application, referring to the application by Serial Number and filing date.
2. Formal Drawings - 8 sheets (Figs. 1-17).

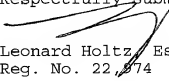
The filing fee of \$690.00 was filed with the Japanese language application. The application contains a total of 42 claims 6 of which are independent. Accordingly, a check in the amount of \$ 890.00 is enclosed to cover the cost of the additional filing fee which includes a multiple dependent fee of

\$260.00. Authorization is given to charge any additional fees which may be required, or to credit any overpayment, to Account No. 06-1378.

The fee of \$130.00 for filing a "Non-English Specification" was previously submitted with the filing of the application.

It is respectfully requested that prosecution on the merits now proceed.

Respectfully submitted,

  
Leonard Holtz, Esq.  
Reg. No. 22,874

Frishauf, Holtz, Goodman, Langer & Chick, P.C.  
767 Third Avenue - 25th Floor  
New York, New York 10017-2023  
Tel. No. (212) 319-4900  
Fax No. (212) 319-5101  
LH:sp

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# TRANSLATION

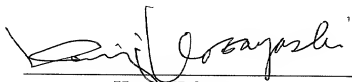
I, Kenji Kobayashi, residing at 2-46-10 Goko-Nishi, Matsudo-shi, Chiba-ken, Japan, state:

that I know well both the Japanese and English languages;

that I translated, from Japanese into English, the specification, claims, abstract and drawings as filed in U.S. Patent Application No. 09/490,631, filed January 24, 2000; and

that the attached English translation is a true and accurate translation to the best of my knowledge and belief.

Dated: March 21, 2000

  
Kenji Kobayashi

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00037/44

## FORMALITIES LETTER

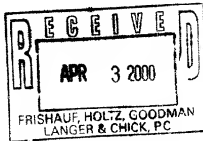


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| APPLICATION NUMBER | FILING/RECEIPT DATE | FIRST NAMED APPLICANT | ATTORNEY DOCKET NUMBER |
|--------------------|---------------------|-----------------------|------------------------|
| 09/490,631         | 01/24/2000          | Yutaka Usami          | 00037/LH               |

Frishauf, Holtz, Goodman, Langer & Chick, P.C.  
767 Third Avenue  
25th Floor  
New York, NY 10017-2023



Date Mailed: 03/30/2000

## NOTICE TO FILE MISSING PARTS OF NONPROVISIONAL APPLICATION



FILED UNDER 37 CFR 1.53(b)

Filing Date Granted

An application number and filing date have been accorded to this application. The item(s) indicated below, however, are missing. Applicants given TWO MONTHS from the date of this Notice within which to file all required items and pay any fees required below to avoid abandonment. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

- The application was filed in a language other than English.

*A copy of this notice **MUST** be returned with the reply.*

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PART 2 - COPY TO BE RETURNED WITH RESPONSE

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TITLE OF THE INVENTION  
ELECTRIC NETWORK SIMULATING METHOD, SIMULATING  
APPARATUS, AND MEDIUM FOR STORING SIMULATION PROGRAM

BACKGROUND OF THE INVENTION

5 The present invention relates to a simulating method and apparatus for grasping the operating status of an electric network in advance in designing the electric network, and a computer-readable storage medium for storing a simulation program.

10 As a conventional method of solving an electric network, for example, as shown in FIG. 15, to obtain voltages at nodes node<sub>1</sub> to node<sub>3</sub> connected to the respective elements in a circuit having resistive elements R<sub>1</sub> and R<sub>2</sub> connected in series with a current source I<sub>1</sub>, the current and voltage formulas of this  
15 circuit are represented by matrix (1) as follows:

$$\begin{bmatrix} I_1 \\ 0 \\ -I_1 \end{bmatrix} = \begin{bmatrix} G_1 & -G_1 & 0 \\ -G_1 & G_1+G_2 & -G_2 \\ 0 & -G_2 & G_2 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} \quad \dots (1)$$

20 where G is the conductance as the reciprocal of a resistance R.

When the above matrix is simply expressed as I = GV, it can be replaced with a mathematical problem for calculating a V matrix by giving I and G matrices. In the above matrix (1), G is LU-decomposed to rewrite  
25 matrix (1) into I = LUV. The LU matrix is comprised of lower and upper triangular matrices having elements represented by matrix (2):

... (2)

5

10

... (3)

... (4)

... (5)

15

are  $L_{11}$ ,  $L_{22}$ ,  $L_{33}$ , .... Values (including zero) set in these diagonal elements are determined depending on the G matrix that describes the circuit.

5 If the circuit is comprised of only resistive elements, and the resistances do not change, the value of the G matrix is also fixed. It is, therefore, possible to make the diagonal elements of the matrix L non-zero. If the diagonal elements become zero, the condition branches to change the order of the elements  
10 of the G matrix in FIG. 16.

Assume that a resistive element has a variable R value. When the impedance value of this resistive element changes depending on the status of the circuit, that the diagonal elements of the L matrix are made  
15 non-zero is not guaranteed beforehand. In an actual algorithm, that the diagonal elements are made non-zero must always be monitored.

If a value except non-zero but infinitely close to zero is set in the diagonal element, a division error  
20 occurs in a numerical calculation expressed by a finite number of bits, and a large calculation error may occur in the subsequent calculation results. In particular, when the differential term of the terminal voltage or current of an element is given as a denominator, for  
25 example, when a calculation item in which a value obtained by subtracting a voltage at time immediately preceding given time from a voltage at the given time

becomes a denominator, a voltage applied across the element is not known beforehand, but known after a simulation. The value of this denominator is unknown. When a differential coefficient is zero, i.e., when the voltage value at the time immediately preceding the given time and the voltage value at the given time are zero or almost zero, the calculation result becomes very poor due to numerical errors. The subsequent calculations are meaningless in practice. An algorithm for always monitoring the number of effective digits even for non-zero values is required.

The above problems are inevitably posed when a solution is obtained by solving a matrix. Even if the concept of the basic solution is simple, an algorithm for solving the above problems is required, resulting in redundant computation as a whole.

#### BRIEF SUMMARY OF THE INVENTION

It is object of the present invention to provide a simulating method and apparatus capable of reliably simulating a circuit operation with a relatively simple algorithm by regarding the circuit operation as movement of particles in a pipe, and a computer-readable storage medium which stores a simulation program.

The present invention is an electric network simulating method comprising the steps of: after setting element cells representing electric functions



of a plurality of circuit elements, intersection cells  
representing functions of electric wiring intersec-  
tions, and connection pipes representing connections  
between the element cells and the intersection cells,  
5 defining a current of an electric network as the number  
of particles moving in the connection pipe per unit  
time, and defining a voltage of the electric network as  
the number of particles present in the connection pipe;  
10 on the basis of the definitions in the defining step,  
setting beforehand, in units of element cells, a rule  
expressing an electric function of each of the circuit  
elements in accordance with a state of the connection  
pipe connected to the element cell, and setting  
15 beforehand, in units of intersection cells, a rule so  
that the numbers of particles present in the connection  
pipes connected to the intersection cell are equal  
to each other and a sum of the numbers of particles  
transferred at the intersection cell becomes zero;  
20 transferring particles between the element cell and the  
connection pipe and between the intersection cell and  
the connection pipe on the basis of the rules set in  
the setting step; and simulating the state of the  
electric network by updating the number of particles  
25 passing through a given connection pipe per unit time  
and the number of particles present in the given  
connection pipe and performing transfer and updating  
processes at least once.

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As described above, according to the simulating method of the present invention, the electric network is defined as the flow of particles, unlike the conventional method of simulating an electric network by solving simultaneous equations. For this purpose, a circuit is replaced with and redefined by element cells representing the electric functions of the circuit elements, the intersection cells representing the functions of the electric wiring intersections, and the connection pipes representing the connections between the element cells and the intersection cells. The rule representing the electric function of each circuit element is set in units of element cells in accordance with the state of the connection pipe. The particles are transferred between the element cells and the connection pipes and between the intersection cells and the connection pipe in accordance with this rule. The number and moving amount of particles in each connection pipe, i.e., the voltage and current can be solely determined. In principle, as described above, all the currents and voltages are redefined as the amounts and movements of particles. In addition, active elements such as a switch and semiconductor element can be equivalently replaced with basic elements such as a resistive element, voltage source, and current source. According to this idea, the relative amount of particles and the moving amount per

ORIGINAL TEXT

unit time in a connected connection pipe are simulated.  
A quick accurate simulation result can be obtained  
for a large electric network unlike the conventional  
simultaneous equation scheme in which errors occur in  
5 principle and a very long processing time is required.

The present invention is not limited to the above  
simulating method, but can extend to a simulating  
apparatus for practicing the simulating method, and  
a storage medium storing a computer program which is  
10 installed in a computer apparatus to perform an  
equivalent simulating method. The simulating method  
and apparatus and the storage medium can achieve a high  
processing speed and high-precision simulation result,  
which cannot be obtained in the conventional method of  
15 solving simultaneous equations, according to the gists  
described above.

Additional objects and advantages of the invention  
will be set forth in the description which follows, and  
in part will be obvious from the description, or may be  
20 learned by practice of the invention. The objects and  
advantages of the invention may be realized and  
obtained by means of the instrumentalities and  
combinations particularly pointed out hereinafter.

#### BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

25 The accompanying drawings, which are incorporated  
in and constitute a part of the specification,  
illustrate presently preferred embodiments of the

invention, and together with the general description given above and the detailed description of the preferred embodiments given below, serve to explain the principles of the invention.

5           FIG. 1 is a circuit diagram showing an electric circuit example according to an embodiment of the present invention;

10           FIG. 2 is a view showing a model in which particles pass through pipes in the circuit example of FIG. 1;

15           FIGS. 3A, 3B, and 3C are views showing an intersection of an electric circuit, and a model for referring to a connection pipe and a model for an intersection cell according to this embodiment;

20           FIGS. 4A and 4B are views showing a model for a diode according to this embodiment;

25           FIGS. 5A and 5B are circuit diagrams showing a capacitor and an equivalent model for the capacitor according to this embodiment;

30           FIGS. 6A, 6B, and 6C are circuit diagrams showing an inductor, and equivalent models for the inductor according to this embodiment;

35           FIG. 7 is a circuit diagram of a leakage transformer;

40           FIG. 8 is a circuit diagram showing the equivalent model for the leakage transformer according to this embodiment;

FIG. 9 is a circuit diagram showing a half-wave voltage resonance inverter;

FIG. 10 is a circuit diagram showing the equivalent model for the half-wave voltage resonance inverter according to this embodiment;

FIG. 11 is a flow chart showing a transient operation analysis process according to this embodiment;

FIG. 12 is a flow chart showing a periodic operation analysis process according to this embodiment;

FIG. 13 is a block diagram showing the arrangement of a simulating apparatus according to this embodiment;

FIG. 14 is a view showing an output example in the simulating apparatus;

FIG. 15 is a circuit diagram for explaining a conventional method of solving an electric network;

FIG. 16 is a flow chart showing the arithmetic process of the electric network;

FIG. 17 is a table showing a cell list according to this embodiment.

#### DETAILED DESCRIPTION OF THE INVENTION

A preferred embodiment of the present invention will be described below with reference to the accompanying drawings.

FIG. 1 shows a closed loop circuit in which a resistor R is connected to a current source 1.

Voltages  $V_1$  and  $V_2$  appear at two terminals of the resistor  $R$ . The current source 1 supplies a current  $i$ . A particle model equivalent to this circuit is shown in FIG. 2.

5           In this particle model, the current source 1 is replaced with a pump  $P$ . This pump  $P$  receives predetermined particles per unit time from a lower pipe 2 and outputs the particles to an upper pipe 3. A function corresponding to the resistor  $R$  is expressed as a  
10           restrictor for particles passing from the upper pipe 3 to the lower pipe 2. A unit volume is used for simply describing the internal volumes of the pipes 2 and 3. The number of particles in each of the pipes 2 and 3 directly represents the particle density.

15           When this particle density is regarded as a voltage, and the number of particles moving per unit time is regarded as a current, the restriction of the particles at the restrictor corresponding to the resistor  $R$  can be expressed as a physical amount.  
20           More specifically, for example, when the current source 1 has 1 A, and the resistor  $R$  has  $100\Omega$ , a potential difference across the resistor  $R$  is 100V. In this case, 1 A is expressed by 1,000 particles, and the degree of restriction of the resistor  $R$  is directly  
25           expressed as 100.

          In a balanced state, the difference corresponding to 100,000 ( $= 1,000 \times 100$ ) particles is produced across

the resistor R. The number of particles is not necessarily positive, but may be zero or negative. The final necessary result is the difference in the number of particles across the resistor R.

5           FIG. 3A shows wiring connections in an electric circuit. An intersection in a general electric circuit is a simple connection and is not defined as an element. All nodes at the intersections are defined as a and are not discriminated from each other in the  
10           circuit.

          To the contrary, as shown in FIG. 3C, an intersection in a particle model is regarded to have the same function as that of an element, and all nodes connected to an intersection cell are different from each other.  
15           That is, three nodes a, b, and c are present. The number of particles present in three pipes connected to this intersection cell are averaged, and the sum of the numbers of particles moving through the pipes at the time of averaging is set to zero.

20           If only a voltage and current are referred to at an intersection, the voltage and current can be expressed as a combination of a given pipe through which particles are moving and a pipe for referring to the given pipe.

25           FIGS. 4A and 4B show an element cell imitating a diode function. This element cell has two terminals having polarities. For example, as shown in FIG. 3A,

assume that the cathode and anode are defined to have positive and negative polarities, respectively. If the number of particles in the cathode-side pipe is larger than that in the anode-side pipe, no particle movement occurs. However, as shown in FIG. 3B, when the cathode and anode are negative and positive, respectively, the particles smoothly move from the anode to the cathode with an increase in the number of particles.

A description of an element cell having this function allows obtaining diode characteristics as the rectification function. If more strict diode characteristics are required, i.e., if a junction capacitance, junction potential, temperature coefficient, and breakdown voltage are also included, a cell may be defined as an arbitrary function including these factors. If it is redundant to describe the diode as one element cell, a diode may be described in detail as a combination of basic linear elements.

A capacitor element will be modeled. A capacitor can be expressed as a current integration formula of a terminal voltage  $V$ , as indicated by equation (6) below. If this is regarded as the sum of regions segmented with finite shortest time intervals, the integration symbol can be expressed as a  $\Sigma$  function. This can be expressed as the primary term between the current and a terminal voltage  $V_{old}$  of the immediately preceding time.



$$v = \frac{1}{C} \int i dt = \frac{dt}{C} \sum i = V_{old} + \frac{dt}{C} i \quad \dots (6)$$

The above equation as a linear equation between the current and voltage has a voltage source as  $V_{old}$  and a resistive component as  $dt/C$ . When this arrangement is decomposed into basic linear elements and equivalently expressed, the capacitor  $C$  shown in FIG. 5A can be expressed as a series connection of a resistive element  $dt/C$  and a voltage source  $V_{old}$ , as shown in FIG. 5B.

A calculation for an arrangement including this capacitor is performed at given time  $t$ , and its operating state at time immediately preceding the given time is already confirmed. In the calculation at given time  $t$ ,  $V_{old}$  can be regarded as a voltage source having a fixed value. The shortest time section  $dt$  of the resistive element is known, and the capacitance of the capacitor  $C$  is also known. These values are also fixed values. Therefore, the behavior of the capacitor at time  $t$  can be expressed by these basic elements.

An inductor element will be modeled below. As represented by equation (7), the left-hand side may be described with  $V$  as in the capacitor. In this case, the right-hand side becomes a current differential term. Equation (7) can be solved, but a current value in an insufficient convergent state is inaccurate. It may often be unpreferable to apply the differential to an inaccurate current.

As indicated by equation (8), the current is defined on the left-hand side, and the voltage integration value is defined on the right-hand side. The current at time  $t$  is the sum of the current value  $L/Dt \times i_{old}$  flowing at time immediately preceding time  $t$  and the current flowing through the resistor, as shown in FIG. 6B. If this is expressed using basic elements, the inductor  $L$  shown in FIG. 6A is expressed as a parallel connection between the resistive element  $L/dt$  and the current source  $i_{old}$ , as shown in FIG. 6C.

$$V = L \frac{di}{dt} = \frac{L}{dt} i - \frac{L}{dt} i_{old} \quad \dots (7)$$

$$i = \frac{1}{L} \int v dt = \frac{dt}{L} \sum V = i_{old} + \frac{dt}{L} V \quad \dots (8)$$

FIG. 7 shows the general notation of a leakage transformer T. In this transformer T, two inductors, i.e.,  $L_p$  and  $L_s$  are magnetically coupled. The degree of coupling is expressed by a coupling coefficient  $k$ . The equations holding on the primary and secondary sides of this transformer T are given by equations (9), (10), and (11)

$$V_p = L_p \frac{di_p}{dt} + M_{ps} \frac{di_s}{dt} \quad \dots (9)$$

$$V_s = L_s \frac{di_s}{dt} + M_{ps} \frac{di_p}{dt} \quad \dots (10)$$

$$M_{ps} = k \sqrt{L_p L_s} \quad \dots (11)$$

where  $M_{ps}$  is the transinductance.

The modification of equations (9), (10), and (11)

in accordance with the same idea as in the inductor yields equations (12) and (13):

$$i_p = i_{ppast} + \frac{dt}{L_p(1 - k^2)} V_p - \frac{Mdt}{L_p L_s - M_{ps}^2} V_s \quad \dots (12)$$

$$i_s = i_{spast} + \frac{dt}{L_s(1 - k^2)} V_s - \frac{Mdt}{L_p L_s - M_{ps}^2} V_p \quad \dots (13)$$

5 where  $i_{ppast}$  and  $i_{spast}$  are currents flowing through the primary and secondary sides at time immediately preceding time  $t$ , and  $V_p$  and  $V_s$  are terminal potential differences on the primary and secondary sides at time  $t$ .

10 These equations are implemented with element cells as a model shown in FIG. 8. That is, this model can be expressed as current source cells  $I_{ppast}$  and  $I_{spast}$ , resistor cells  $R_{TP1}$  and  $R_{TS1}$ ,  $R_{TM1}$ , and  $R_{TM1}$ , and intersection cells.

15 How to recognize this circuit diagram will be described below.

FIG. 9 shows a one-resonator type half-wave voltage resonance inverter. In this inverter, a capacitor C2 is connected to a DC power supply V1 via  
20 a parallel circuit of a diode D1 and capacitor C1. A series circuit of a switch S1 and a parallel circuit of a capacitor C3 and a primary side L1 of the leakage transformer T is connected to the capacitor C3. A diode D2 is connected in parallel to the switch S1  
25 in an opposite polarity, thereby forming a half-wave switch circuit.

A load circuit R1 is connected to a secondary side L2 of the transformer T via a capacitor C4. A series circuit of a resistor R2 and capacitor C5 is connected in parallel to the load circuit R1.

5           This inverter is powered by the DC power supply V1. The half-wave switch circuit made up of the switch S1 and diode D2 turns on/off a parallel resonator made up of the capacitor C3 and the primary side L1 to continue parallel resonance. Part of the resonance  
10           energy is transmitted to the secondary side using the leakage component of the transformer T to drive the load circuit R1.

            This inverter can be replaced with the element cells described above as an equivalent cell circuit  
15           diagram shown in FIG. 10. More specifically, the capacitor C2 is connected in series with a resistive element R<sub>C2</sub> and voltage source V<sub>C2</sub>. The capacitor C3 is connected in series with a resistive element R<sub>C3</sub> and voltage source V<sub>C3</sub>. The capacitor C4 is connected in  
20           series with a resistive element R<sub>C4</sub> and voltage source V<sub>C4</sub>. The capacitor C5 is connected in series with a resistive element R<sub>C5</sub> and voltage source V<sub>C5</sub>. The leakage transformer T is expressed as a combination of current source cells I<sub>TP1</sub>, and I<sub>TS1</sub>, resistor cells  
25           R<sub>TP1</sub>, R<sub>TS1</sub>, R<sub>TM1</sub>, and R<sub>TM1</sub>, and intersection cells X4, X5, X6, and X7.

Reference symbols Y1 and Y2 in FIG. 10 denote

intersection cells each at which three pipes intersect. Reference symbols X1, X2, ..., X8 denote intersection cells each at which four pipes intersect. The internal processes of these pipes are the same although the numbers of intersecting pipes are different. The switch S1 is expressed as a turn-on/off function as in the diode. The ON/OFF state of the switch S1 is determined by a voltage (number of particles) applied to the control terminal. A pulse source P1 is connected to the control terminal, and its reference potential is given as a switch control voltage obtained by making a reference cell (i.e., a cell for referring to the number of particles in a pipe to be referred to) refer to the number of particles at a node 15 and adding the number of particles corresponding to a predetermined pulse voltage to the number of particles referred to by the reference cell. The node names are identical at the intersections in FIG. 9. However, since nodes are newly assigned in FIG. 10, nodes 0 to 39 are set in FIG. 10, while nodes 0 to 7 are set in FIG. 9.

An array shown in FIG. 17 is defined as information for inputting such an equivalent cell arrangement. NME\$ in FIG. 17 is an array for storing the name of an element cell or intersection cell. The first character of the name represents the attribute of the cell. The index of the array starts from "1", and the number

of indices is the number of cells. Since the total number of cells is 32, indices are "1" to "32".

Cells (element cells and intersection cells) required in the present invention are listed in  
5 FIG. 17.

According to the cell list in FIG. 17, NP and NM represent arrays for storing node numbers of nodes to which a cell is connected. When the number of terminals of an element is three or more, arrays N3,  
10 N4, ..., Nn are used following the arrays NP and NM. When an element has polarities, a polarity description becomes important. The polarity has particularly no meaning for an element having no polarity, such as a resistor. However, for convenience, the same notation  
15 is employed. DTA represents an array for storing unique information of a cell. A voltage value is set in a voltage source, a resistance value is set in a resistive element, and no value is set in a cell such as an intersection cell that does not require  
20 particular unique information. When an electric element such as a capacitor, inductor, or leakage transformer, which is expressed as a combination of more basic equivalent cells, the respective equivalent cells describe unique information of the cell. In this  
25 case, the unique information is obtained from the above-described equivalent equations.

A variable new\_i described last loops the process

the number of cells. The number of particles present in a pipe is stored in an array  $V(i)$ , and the number of particles passing per unit time is stored in an array  $II(i)$ , where  $i$  is not the cell number but the pipe node number. The number of arrays  $V$  or  $II$  is equal to the number of pipes. If an initial value is required in analysis of an arrangement including an inductor and capacitor, the values obtained in equations (6) to (8) described above are set as initial data of the arrays  $V$  and  $II$ .

A practical example of a program for transferring particles in cells will be described below. For example, a process for a resistor cell starting from  $R$  is described as follows.

Case "R"

```
V_temp = V(NP(i), t_cell) - V(NM(i), t_cell)
i_temp = V_temp / DTA(i)
V(NP(i), t_cell) = V(NP(i), t_cell) - i_temp
V(NM(i), t_cell) = V(NM(i), t_cell) + i_temp
```

wherein  $V$  is the array for storing the number of particles. If an array is defined as  $V(i, t)$  including the time dimension,  $i$  represents the node number assigned to a pipe. The number  $i$  is not a number corresponding to the loop order of the variable  $new\_i$  defined by the array  $NM(i)$ , and  $t$  represents the number of steps corresponding to calculation time. To obtain a steady solution, the  $t$  term is unnecessary.

When transient operation analysis is required,  $t$  is updated shortest time interval.

$V(NP(i), t_{cell})$  represents the number of particles for the number of steps  $t_{cell}$  in a pipe represented by a positive node array  $NP(i)$ . Similarly,  $V(NM(i), t_{cell})$  is the number of particles in a pipe represented by a negative node array  $NM(i)$ . A difference  $V_{temp}$  between the above numbers of particles is the difference between the numbers of particles in pipes at two terminals of the resistive cell. This difference represents the potential difference. Since the resistance value is input in the DTA array for a resistor cell, a particle flow corresponding to the current to be flowed can be expressed as  $i_{temp} = V_{temp} / DTA(i)$ . In the resistor cell, particles flow from the positive terminal, and the particles equal in number to the input particles are output from the negative terminal. The number of particles corresponding to  $i_{temp}$  is added to or subtracted from the numbers of particles in the pipes at the two terminals of the resistor cell. The foregoing is the cell function as that of the resistor.

The diode cell is a cell having a rectification function of flowing a current in the forward direction but flowing no current in the opposite direction. The diode cell defines a voltage corresponding to the p-n junction potential when the current flows in the



forward direction.

Case"D"

$V\_temp = V(NP(i), t\_cell) - V(NM(i), t\_cell)$

IF  $V\_temp > 0.7$  Then

5  $V(NP(i), t\_cell) = V(NP(i), t\_cell) - V\_temp/2$

$V(NM(i), t\_cell) = V(NM(i), t\_cell) + V\_temp/2$

End if

The potential difference  $V\_temp$  applied to the diode cell in the same manner as described above is calculated. When  $NP(i)$  and  $NM(i)$  are defined as the anode and cathode sides of the diode, respectively,  $V\_temp$  is the potential difference when viewed from the anode side to the cathode side and corresponds to the forward voltage. Assume that the particles move when the forward voltage is 0.7V or more, and the number of moving particles is given as  $V\_temp/2$ . The number of particle at one terminal of the element must be equal to that at the other terminal of the element. A description is made such that the number of particles  $V\_temp/2$  is subtracted from that on the anode side and added to that on the cathode side. When the forward voltage is 0.7V or less, the diode is cut off, and no particles move through the diode. In this case, no description need be made for particle movement.

25 An intersection cell having, e.g., three terminals can be described as follows. An intersection in an electric circuit must receive and output a common

voltage and have the total sum of input/output currents as zero. These two conditions are necessary in solving simultaneous equations. The function to be described for the intersection cell is to satisfy the condition that the numbers of particles between the connected pipes are equal to each other. When this intersection cell functions, the total sum of input/output particle flows (numbers of particles per unit time) consequently becomes zero in the balanced state. In the particle model, obviously, the number of particles (voltage) is the basic physical amount, while the particle flow (current) is a subordinate physical amount.

Case"Y"

V\_temp=

(V(NP(i)),t\_cell)+V(NM(i),t\_cell)+V(N3(i),t\_cell)/3

V(NP(i),t\_cell)=V\_temp

V(NM(i),t\_cell)=V\_temp

V(N3(i),t\_cell)=V\_temp

A current source cell sets a status in which a constant current flows in a steady state. The number of particles per unit time is input and output to the two end pipes. Since the number of times the scan loop of the cell is performed per unit time is proportional to the current value, a value set in the DTA array is a coefficient multiple of the current value. The most understandable method is to set the current value itself in the DTA array and perform the scan loop once

per unit time.

Case "I"

$V(NP(i), t_{cell}) = V(NP(i), t_{cell}) + DTA(i)$

$V(NM(i), t_{cell}) = V(NM(i), t_{cell}) + DTA(i)$

5        An analysis algorithm using these cells will now  
be described.

FIG. 11 is a flow chart showing an example of  
transient operation analysis. When the program runs,  
an array declaration is performed in S1. That is,  
10        a memory area for necessary arrays and variables is  
assured. In S2, information for a circuit to be  
analyzed is input. The input circuit information is  
circuit data of a general electric circuit.

In S3, equivalent cell information is extracted.  
15        In S4, pipe information is extracted. More specifi-  
cally, since the circuit data of the electric circuit  
includes data that cannot be directly expressed as  
element cells, the circuit data are developed as  
circuit information of equivalent cells. In this case,  
20        intersections are replaced with intersection cells, and  
node numbers shared by the intersection positions are  
replaced with those of the intersection cells. The  
node numbers are defined as entirely different node  
numbers. These node numbers are used to identify  
25        pipes. At this moment, a cell list in FIG. 17 is  
almost finished.

In S5, initial values are set. More specifically,

the initial electric state for executing a simulation is set. For example, the initial value for a capacitor is an initial voltage, and the initial value for an inductor is an initial current. The initial voltage indicates that the initial number of particles present in a pipe is determined, i.e., the initial value of the V array is determined. The initial current indicates that the number of particles flows into or out from an inductor per initial unit time is determined as the II array beforehand.

A loop structure will be described. The "transfer of particles in each cell" in this loop structure indicates that particles are transferred in the cells shown in FIG. 17 in accordance with the attributes and pieces of unique information of these cells. This transfer is performed for all the cells.

The first loop (S7) is to simulate the steady state of the circuit at given time. In the first loop, the states of the particles are not balanced as a whole at the beginning. When transfer (S8) is repeated several times, the numbers of particles and particle movements in the pipes converge. When a predetermined convergence condition is satisfied, the state at the given time is regarded to be confirmed, and the first loop is ended. The convergence is determined such that in the first loop, the differences between previous and current values of all or important parts of the V and

II arrays are smaller than the convergence error (S9) and are compared with predetermined convergence condition.

When the first loop is ended, the time advances  
5 a shortest time interval (S9), and the flow returns to the first loop again. This repetition is performed in the second loop (S6). This loop is repeated from time 0 to desired time (S11) and ended (S12). When the time advances the shortest time interval, the following  
10 operation is performed. For example, equivalent conversions shown in FIGS. 5A and 5B and FIGS. 6A and 6B are performed for the capacitor and inductor. For example, in the inductor equivalent model shown in FIG. 6C, a new impedance obtained upon the lapse of the  
15 shortest time interval is calculated by regarding as each II array the total sum of the numbers of particles per unit time flowing in the equivalent model at time preceding the shortest time interval. This impedance is newly set as the unique information of the current  
20 source  $i_{old}$ . The unique information of the voltage source of the equivalent model (FIG. 5B) for the capacitor is similarly calculated from the value of the V array at time preceding the shortest time interval.

In this transient operation analysis, convergence  
25 in the first loop is important and must be strictly determined. If this determination is less strict, the result adversely affects the subsequent operations on

the time basis.

FIG. 12 is a flow chart showing an example of periodic operation analysis. The basic flow (S21 to S24, S27 to S32, and S35) is the same as in the transient operation analysis described above, except that the second loop in the transient operation analysis is determined on the basis of time, while the second loop is ended at the end of the period in the periodic operation analysis (S33), and the third loop is newly installed in the periodic operation analysis.

In the periodic operation analysis, a one-period simulation is complete at the end of the second loop. This indicates that one-period transient operation analysis is performed for the given initial condition. In an actual circuit as well, the periodic operation stabilizes to obtain a steady state several cycles after the start with the initial condition. This also applies to the simulation. To obtain the steady state in the periodic operation, the third loop (S34 and S26) must be repeated several times.

The above operation is equivalent to repetition of transient operation analysis, but the periodic operation analysis has an advantage in that the convergence condition in the first loop can be less strict at the beginning. More specifically, the process for obtaining the steady solution of the period need not always trace a transiently correct process.

Rather, the third loop is repeated a larger number of times to make an element having a large time constant converge.

FIG. 13 is a block diagram showing the arrangement of a simulating apparatus for implementing the above simulation. The simulating apparatus is comprised of a simulation unit 11, input device 12, and output device 13. An example of the input device 12 is a keyboard for directly inputting circuit connection information with key operations, or a storage medium such as a floppy disk or magneto-optical disk for storing circuit connection information in the form of a file and loading the stored circuit connection information to the simulation unit 11. An example of the output device 13 is a display for displaying a simulation result on the monitor screen or a printer for printing it out.

The simulation unit 11 is comprised of an input unit 14, arithmetic unit 16, and output unit 17. The input unit 14 converts the circuit connection information from the input device 12 into information suitable for internal processing and receiving the converted information. The arithmetic unit 16 performs the following arithmetic operations. That is, the arithmetic unit 16 writes the information from the input unit 14 in a circuit information storage area 151 of a storage unit 15, creates an equivalent cell model

on the basis of the written information, and stores the model information in a cell array storage area 152. The arithmetic unit 16 also sequentially stores the number of particles in a pipe connected to each cell and the number of particles moving per unit time in a particle status storage area 153 and sets an initial value in the storage area 153. The output unit 17 converts the arithmetic result of the arithmetic unit 16 into a format suitable for the output device 13.

10 An output example on the monitor screen upon simulating a circuit operation using the simulating apparatus having the above arrangement is shown in FIG. 14. This output example shows the simulation result obtained using the circuit arraignments shown in 15 FIGS. 9, 10, and 17 in accordance with the flow chart of periodic operation analysis shown in FIG. 12. The constants of the circuit elements are listed and output on the left side of the screen, while the node voltage and current waveforms that are desired at the switching 20 period are displayed on the right side of the screen. The conditions for convergence determination are displayed in the four windows on the upper right position of the screen.

Using this simulating apparatus, the operating 25 status of the circuit can be easily grasped, and circuits can be efficiently designed. More specifically, since circuit operation is basically defined as



the movement of particles in each pipe, the arithmetic contents are additions or subtractions. Since no divisions are performed, an overflow as the essential factor of an algorithm does not occur. Calculations  
5 are not interrupted and simulations within predetermined time ranges can be performed regardless of combinations of the circuit arrangements and circuit elements.

Note that although the additions and subtractions  
10 are performed for pipes, divisions may be included depending on the element functions of element cells. For example, in a description of an element cell representing a resistive element, a moving amount of particles corresponding to a current is calculated by a  
15 division using the resistance value. If the resistance value is set to zero, an overflow occurs. However, the resistance value is known beforehand, and appropriate processing can be simply performed. That is, when element cells are properly described, the arithmetic  
20 operations can be separated from the simulating method itself.

The storage medium such as a floppy disk or magnetooptical disk can also store the simulating processing program itself executed by the simulation  
25 unit 11 in addition to the circuit connection information. The simulation unit 11 loads the simulation processing program from the storage medium and then

loads the circuit connection information to perform circuit operation simulations.

As has been described above, according to the present invention, circuit operations are defined as movements of particles in pipes. There can be provided an electric network simulating method capable of reliably simulating circuit operations with a relatively simple algorithm.

In addition, according to the present invention, circuit operations are defined as movements of particles in pipes. There can be provided an electric network simulating apparatus capable of reliably simulating circuit operations with the relatively simple algorithm.

According to the present invention, there can also be provided a storage medium that stores a simulation program capable of reliably simulating circuit operations with the relatively simple algorithm.

WHAT IS CLAIMED IS:

1. An electric network simulating method comprising the steps of:

defining element cells representing electric  
5 functions of a plurality of circuit elements and  
connection pipes representing wiring lines for  
connecting the circuit elements, defining an electric  
network current as the number of particles moving in  
the connection pipe per unit time, and defining an  
10 electric network voltage as the number of particles  
present in the connection pipe;

on the basis of definitions in the defining step,  
setting beforehand, in units of element cells, a rule  
for expressing an electric function of each of the  
15 circuit elements in accordance with a state of the  
connection pipe connected to each of the element cells;

transferring particles between the element cell  
and the connection pipe in accordance with the set  
rule; and

20 simulating the state of the electric network by  
updating the number of particles passing through a  
given connection pipe per unit time in the transferring  
step and the number of particles present in the given  
connection pipe, and performing transfer and updating  
25 processes at least once.

2. An electric network simulating method comprising the steps of:

after setting element cells representing electric functions of a plurality of circuit elements, intersection cells representing functions of electric wiring intersections, and connection pipes representing connections between the element cells and the intersection cells, defining a current of an electric network as the number of particles moving in the connection pipe per unit time, and defining a voltage of the electric network as the number of particles present in the connection pipe;

on the basis of the definitions in the defining step, setting beforehand, in units of element cells, a rule expressing an electric function of each of the circuit elements in accordance with a state of the connection pipe connected to the element cell, and setting beforehand, in units of intersection cells, a rule so that the numbers of particles present in the connection pipes connected to the intersection cell are equal to each other and a sum of the numbers of particles transferred at the intersection cell becomes zero;

transferring particles between the element cell and the connection pipe and between the intersection cell and the connection pipe on the basis of the rules set in the setting step; and

simulating the state of the electric network by updating the number of particles passing through a

given connection pipe per unit time and the number of particles present in the given connection pipe in the transferring step and performing transfer and updating processes at least once.

- 5           3. An electric network simulating method according to one of claims 1 and 2, wherein the setting step includes the step of

when a given one of the circuit elements is a current source, setting a rule for extracting the  
10       number of particles corresponding to a current value per unit time from one of two connection pipes connected to an element cell expressing the given circuit element and giving the number of particles equal in number to the number of extracted particles  
15       to the other one of the two connection pipes.

4. An electric network simulating method according to one of claims 1 and 2, wherein the setting step includes the step of

when a given one of the circuit elements is a  
20       voltage source, setting a rule for making a difference between the number of particles in one of two connection pipes connected to an element cell expressing the given circuit element and the number of particles in the other one of the two connection pipes equal to the  
25       number of particles corresponding to a voltage of the voltage source.

5. An electric network simulating method

according to one of claims 1 and 2, wherein the  
defining step includes the step of

when a given one of the element cells has  
nonlinearity as a function of time, defining the given  
5 circuit element as a combination of an element cell  
for a resistive element and one of an element cell  
expressing a current source and an element cell  
expressing a voltage source, the combination expresses  
linearity equivalent to a behavior of the given circuit  
10 element at given time; and

the setting step includes the steps of

when a certain one of the circuit elements is  
a current source, setting a rule for extracting the  
number of particles corresponding to a current value  
15 per unit time from one of two connection pipes  
connected to an element cell expressing the certain  
circuit element and giving the number of particles  
equal in number to the number of extracted particles  
to the other one of the two connection pipes, and

20 when a specific one of the circuit elements is a  
voltage source, setting a rule for making a difference  
between the number of particles in one of two connec-  
tion pipes connected to an element cell expressing the  
specific circuit element and the number of particles in  
25 the other one of the two connection pipes equal to the  
number of particles corresponding to a voltage of the  
voltage source.

6. An electric network simulating method according to one of claims 1 and 2, wherein the setting step includes the step of

when a given one of the circuit elements has  
5 an impedance characteristic discontinuously changing,  
preparing a plurality of rules for the element cell for  
expressing the given circuit element and selecting one  
of the plurality of rules in accordance with the state  
of the connection pipe connected to the element cell.

10 7. An electric network simulating method according to claim 5, wherein the transferring step and the simulating step include the step of

simulating the state of each element cell at  
initial time so as to simulate a transient phenomenon  
15 of the given circuit element having nonlinearity as  
a function of time, simulating a behavior of the  
nonlinear element at an operating point advancing by  
a shortest time interval, by changing each parameter of  
a combination of the element cells having functions  
20 equivalent to the element cells, and simulating the  
transient phenomenon by repeating the change in  
parameter every time the shortest time interval has  
elapsed.

8. An electric network simulating method  
25 according to claim 6, wherein the transferring step  
and the simulating step include the step of  
simulating a behavior of each element cell at

initial time so as to simulate a transient phenomenon of the given circuit element having the impedance characteristic discontinuously changing, simulating a behavior of the nonlinear element at an operating point advancing a shortest time interval by executing the transferring step in accordance with the rule selected in accordance with the state of the connection pipe connected to the element cell, and simulating the transient phenomenon by repeating the simulating steps every time the shortest time interval has elapsed.

9. An electric network simulating apparatus comprising:

means for defining element cells representing electric functions of a plurality of circuit elements and connection pipes representing wiring lines for connecting the circuit elements, defining an electric network current as the number of particles moving in the connection pipe per unit time, and defining an electric network voltage as the number of particles present in the connection pipe;

means for setting beforehand, on the basis of definitions in the defining means, in units of element cells, a rule for expressing an electric function of each of the circuit elements in accordance with a state of the connection pipe connected to each of the element cells;

means for transferring particles between the



element cell and the connection pipe in accordance with the set rule; and

means for simulating the state of the electric network by updating the number of particles passing through a given connection pipe per unit time in the transferring means and the number of particles present in the given connection pipe, and performing the transfer means and updating process at least once.

10. An electric network simulating apparatus comprising:

means for, after setting element cells representing electric functions of a plurality of circuit elements, intersection cells representing functions of electric wiring intersections, and connection pipes representing connections between the element cells and the intersection cells, defining a current of an electric network as the number of particles moving in the connection pipe per unit time, and defining a voltage of the electric network as the number of particles present in the connection pipe;

means for setting beforehand, on the basis of the definitions in the defining means, in units of element cells, a rule expressing an electric function of each of the circuit elements in accordance with a state of the connection pipe connected to the element cell, and setting beforehand, in units of intersection cells, a rule so that the numbers of particles present in the

connection pipes connected to the intersection cell are equal to each other and a sum of the numbers of particles transferred at the intersection cell becomes zero;

5           means for transferring particles between the element cell and the connection pipe and between the intersection cell and the connection pipe on the basis of the rules set in the setting means; and

10           means for simulating the state of the electric network by updating the number of particles passing through a given connection pipe per unit time and the number of particles present in the given connection pipe in the transferring means and performing transfer and updating processes at least once.

15           11. An electric network simulating apparatus according to one of claims 9 and 10, wherein the setting means includes

20           means for setting, when a given one of the circuit elements is a current source, a rule for extracting the number of particles corresponding to a current value per unit time from one of two connection pipes connected to an element cell expressing the given circuit element and giving the number of particles equal in number to the number of extracted particles  
25           to the other one of the two connection pipes.

12. An electric network simulating apparatus according to one of claims 9 and 10, wherein the

setting means includes

means for setting, when a given one of the circuit elements is a voltage source, a rule for making a difference between the number of particles in one of two connection pipes connected to an element cell expressing the given circuit element and the number of particles in the other one of the two connection pipes equal to the number of particles corresponding to a voltage of the voltage source.

13. An electric network simulating method according to one of claims 9 and 10, wherein the defining means includes

means for defining, when a given one of the element cells has nonlinearity as a function of time, the given circuit element as a combination of an element cell for a resistive element and one of an element cell expressing a current source and an element cell expressing a voltage source, the combination expresses linearity equivalent to a behavior of the given circuit element at given time; and

the setting means includes

means for setting, when a certain one of the circuit elements is a current source, a rule for extracting the number of particles corresponding to a current value per unit time from one of two connection pipes connected to an element cell expressing the certain circuit element and giving the number of

particles equal in number to the number of extracted particles to the other one of the two connection pipes, and

means for setting, when a specific one of the  
5 circuit elements is a voltage source, a rule for making a difference between the number of particles in one of two connection pipes connected to an element cell expressing the specific circuit element and the number of particles in the other one of the two connection  
10 pipes equal to the number of particles corresponding to a voltage of the voltage source.

14. An electric network simulating apparatus according to one of claims 9 and 10, wherein the setting means includes

15 means for, when a given one of the circuit elements has an impedance characteristic discontinuously changing, preparing a plurality of rules for the element cell for expressing the given circuit element and selecting one of the plurality of rules in  
20 accordance with the state of the connection pipe connected to the element cell.

15. An electric network simulating apparatus according to claim 13, wherein the transferring means and the simulating means include

25 means for simulating the state of each element cell at initial time so as to simulate a transient phenomenon of the given circuit element having

nonlinearity as a function of time, simulating a behavior of the nonlinear element at an operating point advancing by a shortest time interval, by changing each parameter of a combination of the element cells having functions equivalent to the element cells, and simulating the transient phenomenon by repeating the change in parameter every time the shortest time interval has elapsed.

16. An electric network simulating apparatus according to claim 14, wherein the transferring means and the simulating means include

means for simulating a behavior of each element cell at initial time so as to simulate a transient phenomenon of the given circuit element having the impedance characteristic discontinuously changing, simulating a behavior of the nonlinear element at an operating point advancing a shortest time interval by executing the transferring means in accordance with the rule selected in accordance with the state of the connection pipe connected to the element cell, and simulating the transient phenomenon by repeating the simulating means every time the shortest time interval has elapsed.

17. A storage medium storing a simulation program loaded and activated in a computer device, the program activating the computer device to generate:

means for defining element cells representing

electric functions of a plurality of circuit elements and connection pipes representing wiring lines for connecting the circuit elements, defining an electric network current as the number of particles moving in  
5 the connection pipe per unit time, and defining an electric network voltage as the number of particles present in the connection pipe;

means for setting beforehand, on the basis of definitions in the defining step, in units of element  
10 cells, a rule for expressing an electric function of each of the circuit elements in accordance with a state of the connection pipe connected to each of the element cells;

means for transferring particles between the  
15 element cell and the connection pipe in accordance with the set rule; and

means for simulating the state of the electric network by updating the number of particles passing through a given connection pipe per unit time in the  
20 transferring step and the number of particles present in the given connection pipe, and performing the transfer means and updating process at least once.

18. A storage medium storing a simulation program loaded and activated in a computer device, the program  
25 activating the computer device to generate:

means for, after setting element cells representing electric functions of a plurality of circuit

elements, intersection cells representing functions of electric wiring intersections, and connection pipes representing connections between the element cells and the intersection cells, defining a current of  
5 an electric network as the number of particles moving in the connection pipe per unit time, and defining a voltage of the electric network as the number of particles present in the connection pipe;

means for setting beforehand, on the basis of the  
10 definitions in the defining step, in units of element cells, a rule expressing an electric function of each of the circuit elements in accordance with a state of the connection pipe connected to the element cell, and setting beforehand, in units of intersection cells,  
15 a rule so that the numbers of particles present in the connection pipes connected to the intersection cell are equal to each other and a sum of the numbers of particles transferred at the intersection cell becomes zero;

20 means for transferring particles between the element cell and the connection pipe and between the intersection cell and the connection pipe on the basis of the rules set in the setting step; and

means for simulating the state of the electric  
25 network by updating the number of particles passing through a given connection pipe per unit time and the number of particles present in the given connection

pipe in the transferring means and performing transfer and updating processes at least once.

19. A storage medium storing the simulation program according to one of claims 17 and 18, wherein  
5 the setting means includes

means for setting, when a given one of the circuit elements is a current source, a rule for extracting the number of particles corresponding to a current value per unit time from one of two connection pipes  
10 connected to an element cell expressing the given circuit element and giving the number of particles equal in number to the number of extracted particles to the other one of the two connection pipes.

20. A storage medium storing the simulation program according to one of claims 17 and 18, wherein  
15 the setting means includes

means for setting, when a given one of the circuit elements is a voltage source, a rule for making a difference between the number of particles in one of  
20 two connection pipes connected to an element cell expressing the given circuit element and the number of particles in the other one of the two connection pipes equal to the number of particles corresponding to a voltage of the voltage source.

21. A storage medium storing the simulation program according to one of claims 17 and 18, wherein  
25 the defining means includes



means for defining, when a given one of the  
element cells has nonlinearity as a function of time,  
the given circuit element as a combination of an  
element cell for a resistive element and one of an  
5 element cell expressing a current source and an element  
cell expressing a voltage source, the combination  
expresses linearity equivalent to a behavior of the  
given circuit element at given time; and

the setting means includes

10 means for setting, when a certain one of the  
circuit elements is a current source, a rule for  
extracting the number of particles corresponding to a  
current value per unit time from one of two connection  
pipes connected to an element cell expressing the  
15 certain circuit element and giving the number of  
particles equal in number to the number of extracted  
particles to the other one of the two connection pipes,  
and

means for setting, when a specific one of the  
20 circuit elements is a voltage source, a rule for making  
a difference between the number of particles in one  
of two connection pipes connected to an element cell  
expressing the specific circuit element and the number  
of particles in the other one of the two connection  
25 pipes equal to the number of particles corresponding to  
a voltage of the voltage source.

22. A storage medium storing the simulation

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program according to one of claims 17 and 18, wherein the setting means includes

means for, when a given one of the circuit elements has an impedance characteristic discontinuously changing, preparing a plurality of rules for the element cell for expressing the given circuit element and selecting one of the plurality of rules in accordance with the state of the connection pipe connected to the element cell.

23. A storage medium storing the simulation program according to claim 22, wherein the transferring means and the simulating means include

means for simulating the state of each element cell at initial time so as to simulate a transient phenomenon of the given circuit element having nonlinearity as a function of time, simulating a behavior of the nonlinear element at an operating point advancing by a shortest time interval, by changing each parameter of a combination of the element cells having functions equivalent to the element cells, and simulating the transient phenomenon by repeating the change in parameter every time the shortest time interval has elapsed.

24. A storage medium storing the simulation program according to claim 23, wherein the transferring means and the simulating means include

means for simulating a behavior of each element

cell at initial time so as to simulate a transient phenomenon of the given circuit element having the impedance characteristic discontinuously changing, simulating a behavior of the nonlinear element at  
5 an operating point advancing a shortest time interval by executing the transferring step in accordance with the rule selected in accordance with the state of the connection pipe connected to the element cell, and simulating the transient phenomenon by repeating the  
10 simulating steps every time the shortest time interval has elapsed.

# ABSTRACT OF THE DISCLOSURE

According to an electric network simulating method, element cells representing electric functions of a plurality of circuit elements and connection pipes representing wiring lines for connecting the circuit elements are defined. A current is defined as the number of particles moving through the connection pipe per unit time, and a voltage is defined as the number of particles present in the connection pipe. A rule for expressing the electric function of each circuit element in accordance the state of the connection pipe is set beforehand in units of element cells. The particles are transferred between the element cell and the connection pipe in accordance with the rule. The state of the electric network is simulated in accordance with the number of particles passing through the connection pipe per unit time and the number of particles present in the connection pipe.

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DATE RECEIVED

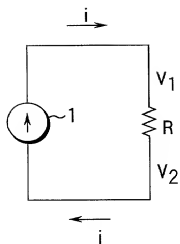


FIG. 1

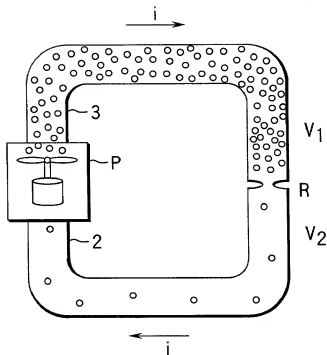


FIG. 2

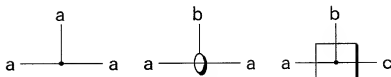


FIG. 3A

FIG. 3B

FIG. 3C

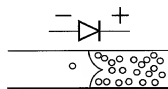


FIG. 4A



FIG. 5A

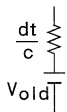


FIG. 5B

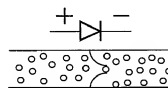


FIG. 4B



FIG. 6A

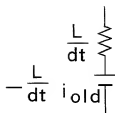


FIG. 6B

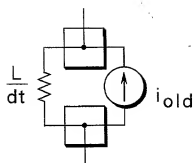


FIG. 6C

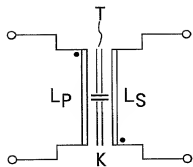


FIG. 7

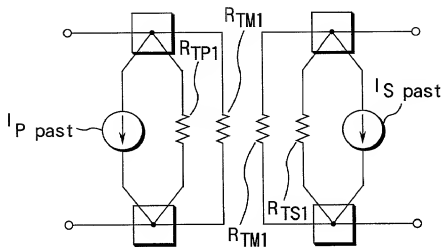


FIG. 8

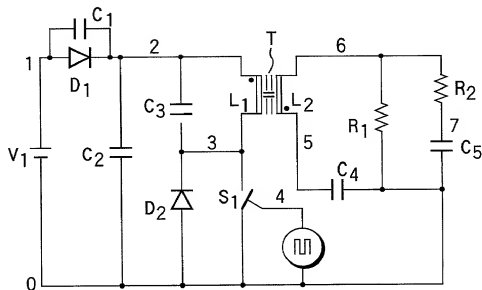


FIG. 9



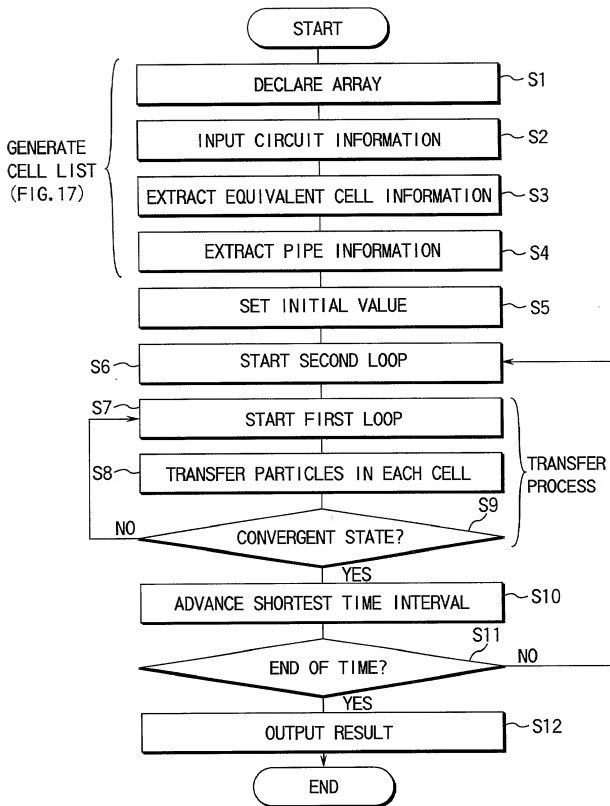
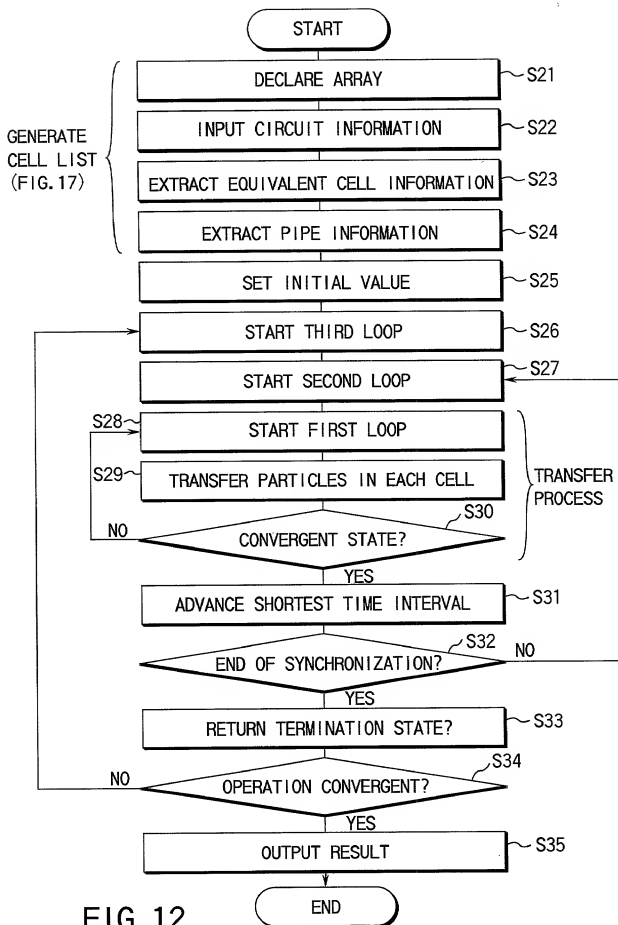


FIG. 11





Panod=0.000019

Ct = 3.8E-08

C2 = 0.000046

C3 = 6.8E-09

C4 = 0.000001

C5 = 4.3E-09

L1 = 0.0012

L2 = 0.0028

R1 = 600

R2 = 20

katu = 0.65

M = 1.19147E-0.3

V1 = 200

L1 = 0.0012

L2 == 0.0028

M = 1.19147E-0.3

katu = 0.65

----- OUTPUT SECTION -----

V(11)\_max = 683.3895

V(11)\_min = -1.087639

V(30)\_max = 278.2092

V(30)\_min = -388.625

I(R1)\_max = 0.4600302

I(R1)\_min = -0.6466231

I(R2)\_max = 0.5038309

I(R2)\_min = -0.563192

I(L1)\_max = 1.837644

I(L1)\_min = -1.170115

I(L2)\_max = 0.6056873

I(L2)\_min = -0.9513868

1 150 500 10

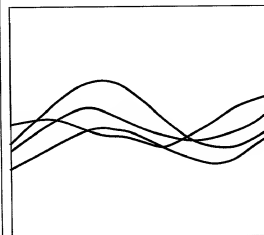
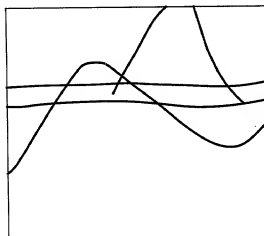


FIG.14

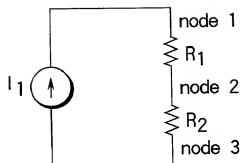


FIG. 15

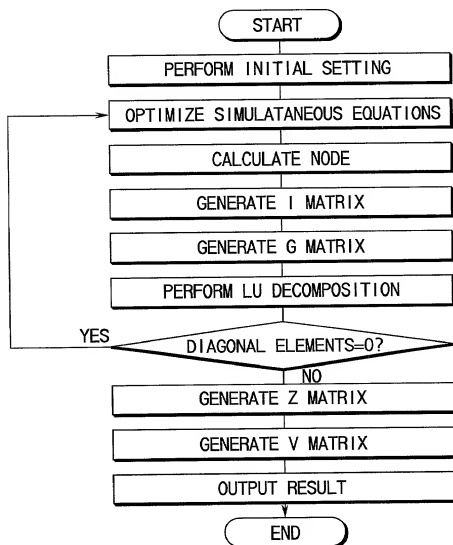


FIG. 16

| CELL LIST         |                           |            |   |
|-------------------|---------------------------|------------|---|
| CELL NUMBER       | CONNECTION<br>NODE NUMBER |            | UNIQUE INFORMATION  |
| NME\$(1)="V1":    | NP(1)=1:                  | NM(1)=0:   | DTA(1)=V1   |
| NME\$(2)="D1":    | NP(2)=1:                  | NM(2)=2:   |   |
| NME\$(3)="X1":    | NP(3)=2:                  | NM(3)=3:   | N3(3)=4: N4(3)=5  |
| NME\$(4)="X2":    | NP(4)=9:                  | NM(4)=10:  | N3(4)=11: N4(4)=12  |
| NME\$(5)="Y1":    | NP(5)=0:                  | NM(5)=7:   | N3(5)=14:   |
| NME\$(6)="RC2":   | NP(6)=3:                  | NM(6)=6:   | DTA(6)=dt/C2  |
| NME\$(7)="VC2":   | NP(7)=6:                  | NM(7)=7:   | DTA(7)=0  |
| NME\$(8)="X1":    | NP(8)=2:                  | NM(8)=3:   | N3(8)=4: N4(8)=5  |
| NME\$(9)="RC3":   | NP(9)=5:                  | NM(9)=8:   | DTA(9)=dt/C3  |
| NME\$(10)="VC3":  | NP(10)=8:                 | NM(1)=9:   | DTA(10)=0   |
| NME\$(11)="V2":   | NP(11)=13:                | NM(11)=10: |   |
| NME\$(12)="S1":   | NP(12)=11:                | NM(12)=15: | N3(12)=39: N4(12)=15:<br>DAT(12)=1                        |
| NME\$(13)="X3":   | NP(13)=13:                | NM(13)=14: | N3(13)=15: N4(13)=16                                      |
| NME\$(14)="P1":   | NP(14)=39:                | NM(14)=15: | DAT(14)=50: DAT2(14)=0:<br>DAT3(14)=223                   |
| NME\$(15)="X4":   | NP(15)=4:                 | NM(15)=17: | N3(15)=18: N4(15)=19                                      |
| NME\$(16)="X5":   | NP(16)=12:                | NM(16)=20: | N3(16)=21: N4(16)=22                                      |
| NME\$(17)="RTP1": | NP(17)=18:                | NM(17)=21: | DAT(17)=L1 * (1- $\text{ketu} \cdot \text{ketu}$ )/dt     |
| NME\$(18)="RTM1": | NP(18)=23:                | NM(18)=26: | DAT(18)=(L1 * L2 - M * M)/<br>(M * dt)                    |
| NME\$(19)="ITP1": | NP(19)=20:                | NM(19)=17: | DAT(19)=0   |
| NME\$(20)="X6":   | NP(20)=23:                | NM(20)=24: | N3(20)=25: N4(20)=30                                      |
| NME\$(21)="X7":   | NP(21)=26:                | NM(21)=27: | N3(21)=28: N4(21)=29                                      |
| NME\$(22)="RTS1": | NP(22)=24:                | NM(22)=27: | DAT(22)=L2 * (1- $\text{ketu} \cdot \text{ketu}$ )/<br>dt |
| NME\$(23)="RTM1": | NP(23)=19:                | NM(23)=22: | DAT(23)=(L1 * L2 - M * M)/<br>(M * dt)                    |
| NME\$(24)="ITS1": | NP(24)=28:                | NM(24)=25: | DTA(24)=0   |
| NME\$(25)="Y2":   | NP(25)=30:                | NM(25)=31: | N3(25)=32   |
| NME\$(26)="R1":   | NP(26)=32:                | NM(26)=36: | DAT(26)=R1  |
| NME\$(27)="R2":   | NP(27)=31:                | NM(27)=33: | DAT(27)=R2  |
| NME\$(28)="X8":   | NP(28)=35:                | NM(28)=36: | N3(28)=37: N4(28)=16                                      |
| NME\$(29)="RC5":  | NP(29)=33:                | NM(29)=34: | DTA(29)=dt/C5   |
| NME\$(30)="VC5":  | NP(30)=34:                | NM(30)=35: | DTA(30)=0   |
| NME\$(31)="RC4":  | NP(31)=29:                | NM(31)=38: | DTA(31)=dt/C4   |
| NME\$(32)="VC4":  | NP(32)=38:                | NM(32)=37: | DTA(32)=0   |

new\_i=32

FIG. 17

As a below named inventor, I declare:

that I verily believe myself to be the original, first and sole (if only one individual inventor is listed below) or an original, first and joint inventor (if more than one individual inventor is listed below) of the invention in

ELECTRIC NETWORK SIMULATING METHOD, SIMULATING APPARATUS,  
AND MEDIUM FOR STORING SIMULATION PROGRAM

the specification of which is attached hereto unless the following box is checked.

☐ was filed on \_\_\_\_\_ as United States Application  
or PCT International Application No. \_\_\_\_\_, and  
was amended on \_\_\_\_\_ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information of which is material to patentability as defined in 37 CFR 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or 365 (b) of any foreign application(s) for patent or inventor's certificate, or 35 U.S.C. 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed:

| <u>Country</u> | <u>Category</u> | <u>Application No.</u> | <u>Filing Date</u> | <u>Priority Claim</u> |
|----------------|-----------------|------------------------|--------------------|-----------------------|
| Japan          | Patent          | 11-016823              | January 26, 1999   | Yes                   |

And I hereby appoint Leonard Holtz (Reg. No. 22,974), Herbert H. Goodman (Reg. No. 17,081), Thomas Langer (Reg. No. 27,264), Marshall J. Chick (Reg. No. 26,853), Richard S. Barth (Reg. No. 28,180), Douglas Holtz (Reg. No. 33,902) and Robert P. Michal (Reg. No. 35,614) each of whose address is 767 Third Avenue - 25th Floor, New York, N.Y. 10017-2023, or any one of them, my attorneys with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent & Trademark Office connected therewith, and request that correspondence be directed to Frishauf, Holtz, Goodman, Langer & Chick, P.C., 767 Third Avenue - 25th Floor, New York, N.Y. 10017-2023.

I declare further that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

## DECLARATION FOR PATENT APPLICATION

99S1055

I declare further that my citizenship, residence and post office address are as stated below next to my name:

Inventor: (Signature)DateResidence and post office address

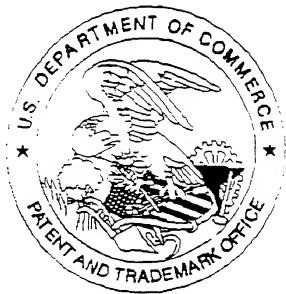
Yutaka Usami  
Yutaka Usami

Date: January 12, 2000Citizen of: Japan3-71-1, Tachibana, Ohitocho,  
Tagata-gun, Shizuoka-ken, JapanDate: January 12, 2000Citizen of: Japan1-2-31, Kunikubo, Fuji-shi,  
Shizuoka-ken, Japan

Takashi Kobayashi  
Takashi Kobayashi

Date:Citizen of: JapanDate:Citizen of: JapanDate:Citizen of: JapanDate:Citizen of: JapanDate:Citizen of: JapanDate:Citizen of: Japan

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There are only 8 <sup>sets</sup> of drawings present.